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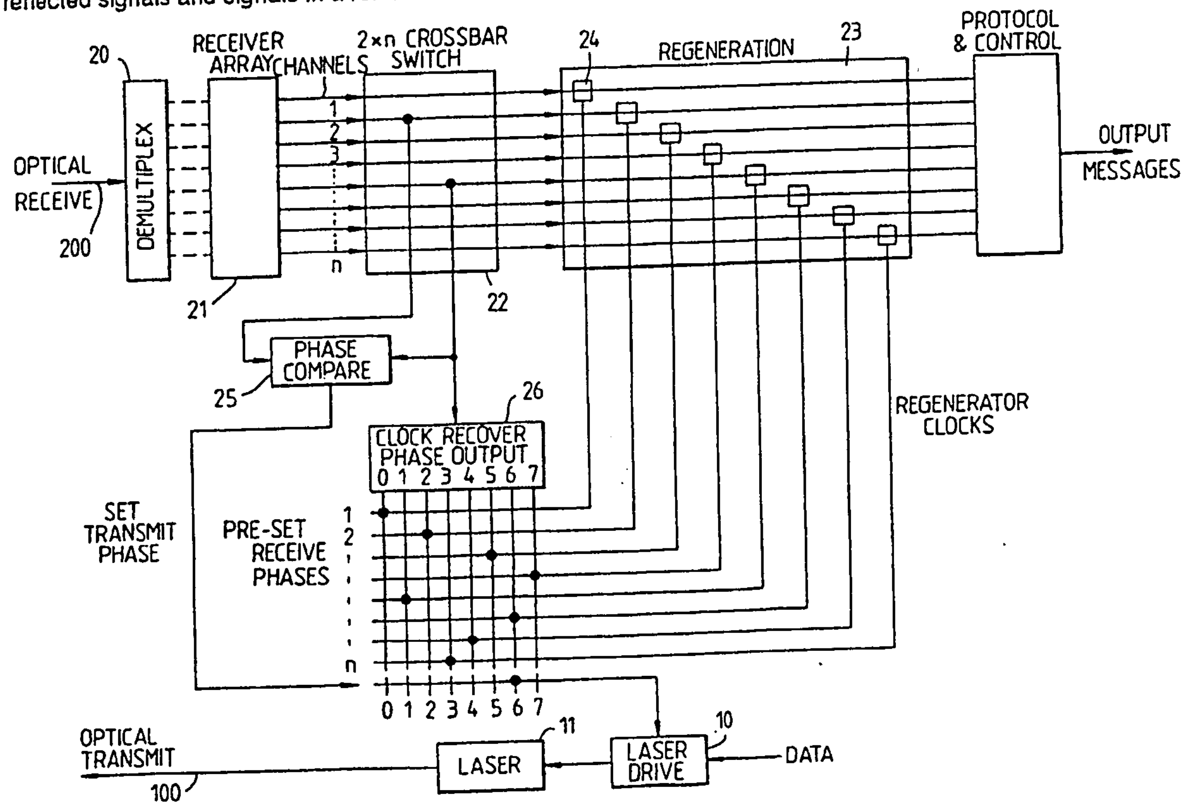
# (54) Synchronous multi-wavelength optical terminal

(57) A terminal for a star-coupled synchronous wavelength multiplexed optical network. Regeneration and retiming of received demultiplexed signals is performed under control of clock signals derived from clock information extracted from one receiver channel, the derived clock signals having incremental phase differences relative to the extracted clock. The derived clock signal for each channel is selected in accordance with the optical propagation delay characteristics of the channel. The terminal transmitted clock is selected in accordance with the phase difference between the terminals own reflected signals and signals in a reference channel.

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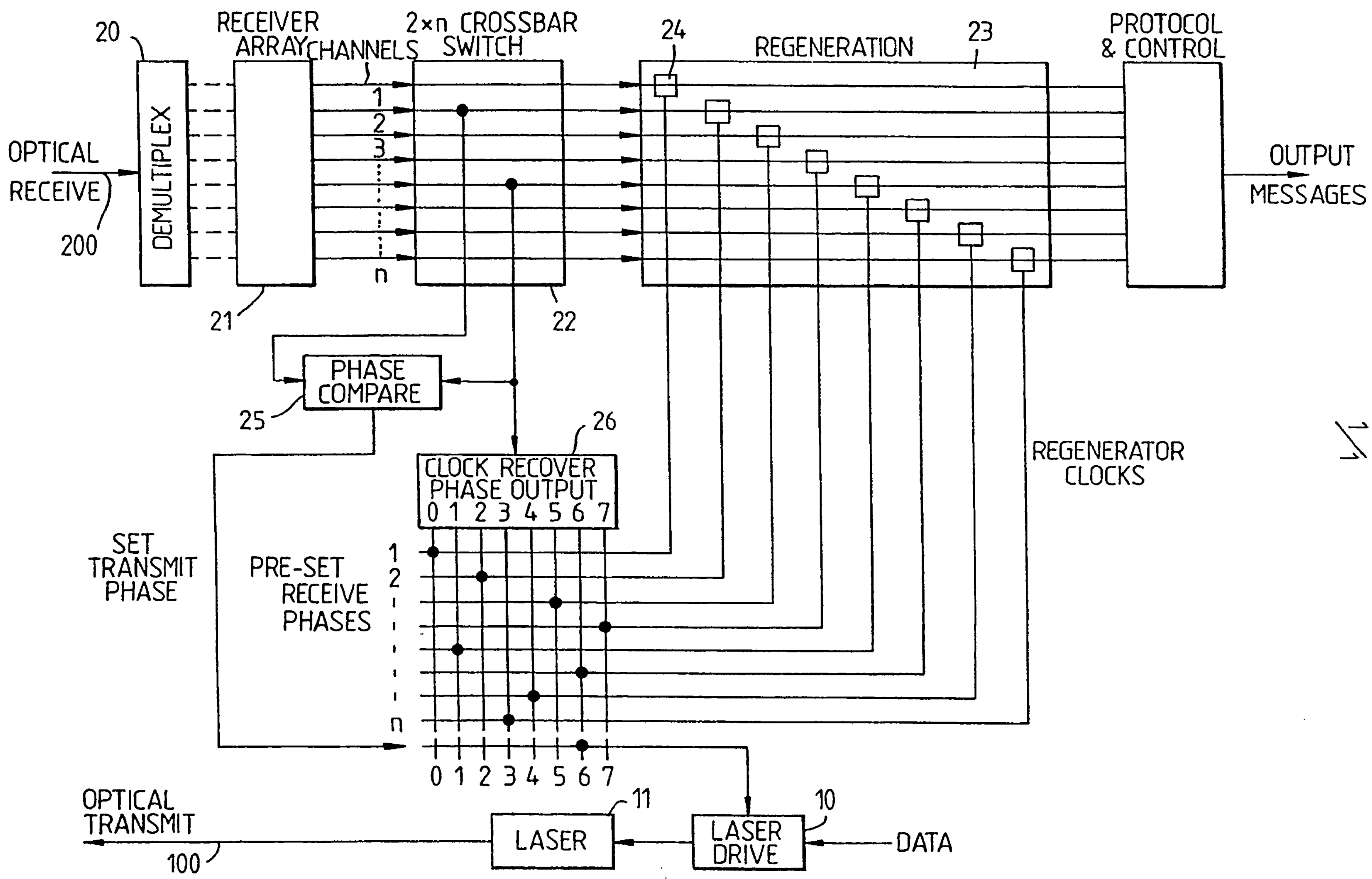
# Synchronous Multi-wavelength Optical Terminal

This invention relates to a terminal for a synchronous multi-wavelength optical network.

UK Patent Application No. GB 2 224 611A discloses a multi-wavelength optical network having a plurality of wavelength multiplexed nodes or terminals each having a single frequency optical signal transmitter and a multi-wavelength optical signal receiver. An optical signal transmission network includes a passive optical star coupling means interconnecting all the nodes by a single optical path to each node whereby single frequency optical signals transmitted from each node are propagated via the coupling means to all the nodes. Each node also includes wavelength demultiplexing means through which received signals are applied to the receiver. Each node has timing and control means arranged to control the timing of signals transmitted by the node over the network so that the optical signals from all the nodes are synchronous at the coupler. A feature of the system is that each node not only receives all the signals from all the other nodes via its single optical path, it also receives back its own signals transmitted to the coupler.

In the prior art receiver, because the individual transmission paths from the nodes to the star coupler may all be of different lengths an important


20
RECEIVER ARRAY
CHANNELS
2×n CROSSBAR SWITCH
24
REGENERATION
23
PROTOCOL & CONTROL
OPTICAL RECEIVE
200
DEMULTIPLEX
1
2
3
n
OUTPUT MESSAGES
21
22
PHASE COMPARE
25
26
CLOCK RECOVER PHASE OUTPUT
0 1 2 3 4 5 6 7
REGENERATOR CLOCKS
SET TRANSMIT PHASE
PRE-SET RECEIVE PHASES
OPTICAL TRANSMIT
100
LASER
11
LASER DRIVE
10
DATA

feature is the provision of clock extraction means to enable synchronous operation of the network. Although the concept of the network is that all the node signals are synchronised at the star coupler, chromatic dispersion of the different wavelength signals will result in a loss of accurate synchronisation of the signals by the time they reach a node. The degree of loss of synchronisation of individual signals will be affected by the length of the optical path from the coupler to the node.

It is an object of the present invention to provide a terminal or node for a synchronous multi-wavelength optical network which terminal has means for compensation for chromatic dispersion in the optical path to the terminal, irrespective of the length of the optical path.

According to the invention there is provided a terminal for a star coupled synchronous multi-wavelength optical network, the terminal including means for demultiplexing a plurality of received wavelength multiplexed signal channels, means for extracting clock signals from one of the received channels, means for generating from the extracted clock signals a plurality of like clock signals having respectively different incremental phase shifts relative to the extracted clock signals, a regeneration and retiming means for each signal channel, and means for applying to each regeneration and retiming means a predetermined one of said generated clock signals to control regeneration and retiming of the signals in the signal channel.

An embodiment of the invention is now described with reference to the accompanying drawing which is a block schematic diagram of a terminal.

The terminal is connected to the network star coupler by means of transmit and receive optical fibres 100, 200. Data to be transmitted to the network is fed via a driver circuit 10 to a laser 11 coupled to the transmit fibre 100. The transmitted signal also includes clock data. The receive fibre 200 is coupled to an optical wavelength demultiplexer 20 wherein the signals from all the terminals, including this terminal, are demultiplexed into individual channels. The demultiplexer may be one as disclosed in "Monolithic GaInAs/InP Photodetector Arrays for High-Density Wavelength Division Multiplexing (HDWDM) Applications", W.S. Lee et al, Electronics Letters, 1st September 1988, Vol.24, No. 18, pp. 1143-5. The wavelength demultiplexed optical channels are fed to a receiver array 21 having a photodetector for each channel to convert the optical signals to electrical signals. The electrical channel signals are fed, via a 2xn crossbar switch 22 to an array 23 of regeneration and retiming circuits 24. In the crossbar switch 22 connections are made from two channels to a phase comparator circuit 25. One of these connections is to the channel on which signals are received from a master or reference station, e.g. channel 2. The other connection is made to the terminal's own receive channel, e.g. channel 5 if the terminal is terminal number 5. The connection from channel 5 also feeds a clock recovery circuit 26 which recovers a clock signal from the terminal's own signals received back from the network coupler. The clock recovery circuit is arranged to provide a plurality of clock outputs differing incrementally in phase. The regenerators 24 are each connected via a second crossbar switch to an appropriate one of the clock phase outputs as will be explained below.

The output of the phase comparison between

the signals received on channels 2 and 5 is used to select an appropriate clock phase to control the laser drive circuit 10. Finally the regenerated and retimed channel signals are applied to a protocol and control circuit which will process the received signals in all the channels to extract and output those signals addressed to the terminal.

To operate the terminal it is first necessary to determine the optical path length from the terminal to the network star coupler. From this length information, plus the knowledge of the differential delay per wavelength induced by chromatic dispersion each terminal can predict the expected differential delay for every one of its wavelength channels. This can be used to select appropriately phase shifted clocks for each regenerator, from the single clock recovery circuit, thus avoiding the need for individual clock recovery.

When a terminal which is attached to the network and is first switched on it will be able to receive signals from the master terminal and any other terminals which are active. The sequence of operating steps is as follows:

1. The terminal transmits a signal via the star coupler back to its own receiver (the receiver for its own transmitter wavelength), and measures the round trip delay (the signal is reflected from the centre of the star). This provides a measure of the fibre length from the centre of the star to the terminal. The circuitry required to perform this measurement is not shown but is readily designed by those skilled in the art. Alternatively the path length may be known from other sources, e.g. the optical fibre length may have been measured at the time of installation.

2. The terminal performs clock recovery and signal regeneration on the master channel. If it does not know which is the master, it switches this function from one channel to the next by means of the crossbar switch 22 till it acquires the master channel. The identity of the master can be contained within the transmitted signal packet headers.

3. From the path length information, plus the knowledge of the differential delay per wavelength induced by chromatic dispersion, each terminal predicts the differential delay for every one of its receiver wavelength channels. The slope of delay versus wavelength due to chromatic dispersion will be different for ordinary and dispersion shifted fibres, however it will be very similar for different types of non-shifted fibre when operated at 1.5 microns. This information is then used to set up appropriately phase shifted clocks for each regenerator, from the single clock recovery circuit, thus avoiding the need for individual clock recovery for every channel.

4. Except for its own channel, all the received signals should now be correctly regenerated. The phase of its own transmitter drive signal is now changed until the differential phase between the master channel and its own channel is equal to that predicted from step 3 above (typically this differential phase is forced to zero). The whole system is now phase synchronous at the centre of the star.

5. Frame synchronism may now be achieved by stepping and testing for synchronism with the master frame.

6. The system is now fully synchronised at the centre of the star.

CLAIMS

1. A terminal for a star coupled synchronous multi-wavelength optical network, the terminal including means for demultiplexing a plurality of received wavelength multiplexed signal channels, means for extracting clock signals from one of the received channels, means for generating from the extracted clock signals a plurality of like clock signals having respectively different incremental phase shifts relative to the extracted clock signals, a regeneration and retiming means for each signal channel, and means for applying to each regeneration and retiming means a predetermined one of said generated clock signals to control regeneration and retiming of the signals in the signal channel.

2. A terminal according to claim 1 wherein the extracted clock signals are obtained from a receiver signal channel in which the received signals are those transmitted from the terminal to the synchronous network and reflected back from the network in one of the received wavelength multiplexed signal channels.

3. A terminal according to claim 1 or 2 wherein the generated clock signals applied to a regeneration and retiming means are selected in accordance with predicted propagation delay characteristics of the demultiplexed signals to be regenerated.

4. A terminal according to claim 1, 2 or 3 including means for comparing the phase of received signals, being those transmitted from the terminal to the synchronous network and reflected back from the network in one of the received wavelength multiplexed signal channels, with received signals in another channel, being signals transmitted to the network from a different reference terminal, means for selecting one of said generated clock signals in dependence on said phase comparison and means for applying said selected clock signals to control transmission of signals from the terminal to the network.

5. A terminal according to claim 3 including means for transmitting to the synchronous network a signal which signal is reflected from the network back to the terminal and means for measuring the delay in the reflected signal to determine the optical path propagation delay characteristics of the received signals.

6. A terminal substantially as described with reference to the accompanying drawing.